vii. System Thermal Mass and Cooldown/Warmup Time Estimates

The calculated mass of those parts of a 9.7 m dipole which will operate at 4.6 K is 8500 lb. Other magnets have been scaled at the mass per unit length to produce the estimated thermal mass value given in Table 3-11.

Table 3-11 also shows a rudimentary cooldown calculation which assumes that the accelerator is divided into four sections of three sextants each for the cooldown. The calculation assumes that four waves of helium will be used in the cooldown process. The first wave leaves the refrigerator at 40 K, the second at 15 K, the third at 5 K and the fourth at 4.3 K. The asterisk shown in the table for each wave shows the limiting factor for each wave. Special calculations were made to estimate the output of the refrigerator at the higher temperatures required for operation during waves 1 and 2. Figure 3-4 shows the calculated capacity of the refrigerator below 5 K for various mixes of liquefaction and refrigeration modes. Three "limit lines" bound the allowed operating region in this figure. These three are (1) the maximum mass flow allowable through the expanders, (2) the main compressor flow rate, and (3) the heat exchanger available surface area.

It has been estimated, without any safety factor, that 6.3 days will be required to cooldown RHIC. This includes a period of 24 hours to soak the magnets at temperature to remove the last vestiges of heat which might cause hot spots. The cooldown process will probably not be 100% efficient in the early operations, so it is wise to not plan on less than seven days for the cooldown.

The energy necessary to warm the magnets to room temperature from operating temperature is to be provided by electric resistance heaters inserted into the magnet laminations. A small flow of helium may be provided during the time that the heaters are powered to spread the heat from the laminations to parts of the system not in contact with the laminations.

Table 3-11 RHIC Cooldown Calculations

9.7 m Dipole Cold Mass @ 8500 lb	3855600	g
Mass per Unit Length	397485	g/m
Dipole Thermal Mass (4-300 K, 81 J/g)	3.1230×10^{8}	J
Thermal Mass per Unit Length	32196247	J/m
Total Magnet Length (2 rings):		
396 dipoles @ 9.7 m	3841.0	m
492 quad/correctors @ 3.2 m	1574.4	m
Total Length for 2 rings	5416	m

COOLDOWN THERMAL MASS FOR 1 LOOP OF 4

Temperature Range K	Enthalpy Change J/g	Joules/Loop J	Density Change g/L	Helium Loop g
300-40	80.790	4.348×10^{10}	15.2	7.1861×10^{5}
40-15	0.296	1.5902×10^{8}	34.4	1.6211×10^{6}
15-6	0.013	6.8722×10^{6}	83.7	3.9458×10^{6}
6-4	0.001	5.3170×10^{5}	.0	0
Total: 300-4	81.099	4.364×10^{10}	133.4	6.2855×10^{6}

REFRIGERATOR OUTPUT

Wave #	Apparent Refrig./Loop W	Apparent Liquifac./Loop g/s	Pressure Drop/Loop bar	Approx. Time/Wave h
Wave 1: 40 K, 15 bar - 4 @ 100 g/s*	1.356×10^{5}	2.2	7.1	89.1
Wave 2: 15 K, 15 bar - 4 @ 100 g/s	7.4259×10^{3}	75.0*	1.0	5.9
Wave 3: 6 K, 15 bar - 4 @ 100 g/s	6.1527×10^{1}	35.0*	0.3	31.0
Wave 4: 4.5 K, Cool loop to 4.5 K, 4.5 bar	5×10^{3}	12.5	Temp Soaking	24.0*

COOL DOWN TIME	Total	=	150.0 h
		=	6.3 d

*Indicates limiting factor

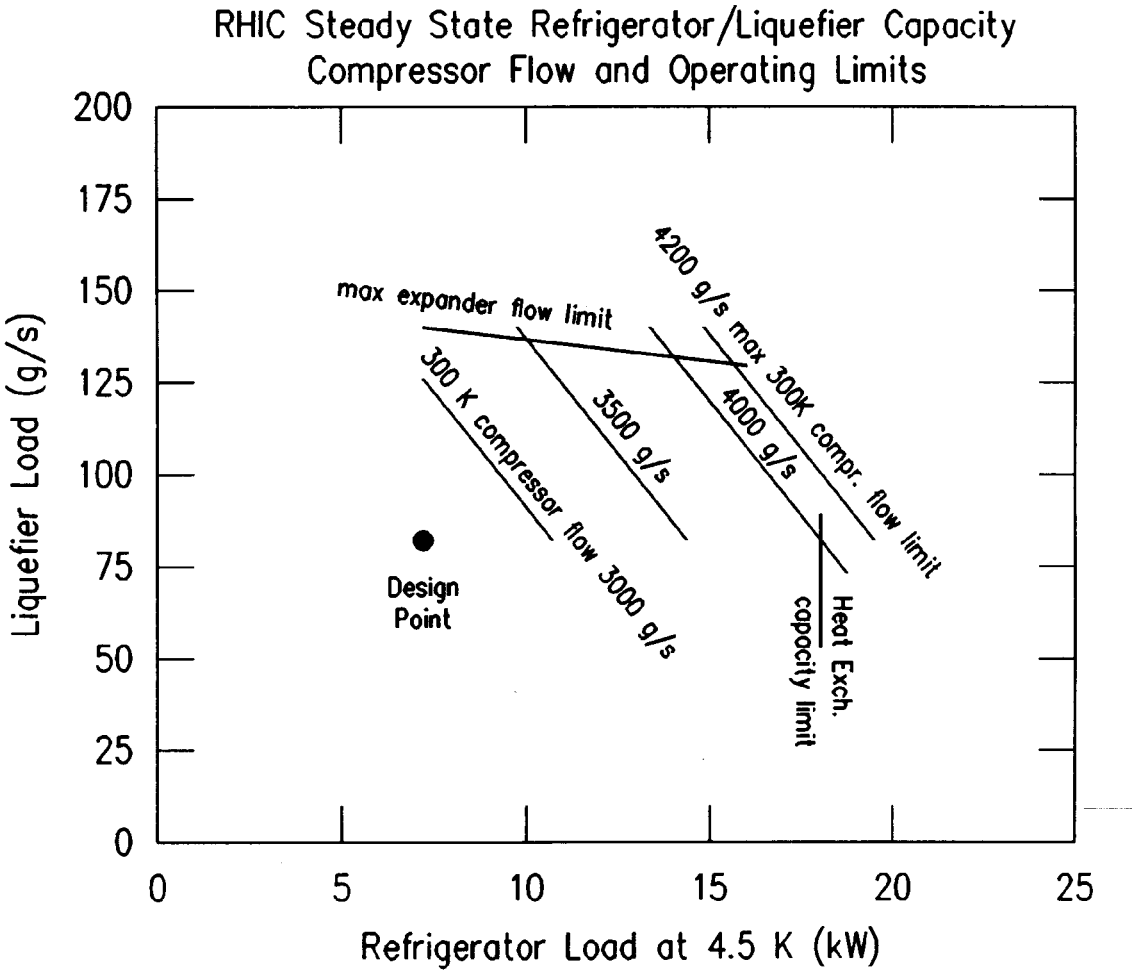

Fig. 3-4. RHIC steady state refrigerator/liquefier capacity compressor flow and operating limits.